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(54) **ORGANIC LIGHT-EMITTING DISPLAY APPARATUS AND METHOD FOR MANUFACTURING THE SAME**

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(52) **U.S. Cl.**
CPC **H01L 51/5253** (2013.01)

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USPC 257/40, 88, 98, E33.074; 438/28, 29, 2; 313/504; 445/25

See application file for complete search history.

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(57) **ABSTRACT**

An organic light-emitting display apparatus includes: a substrate, and an organic light-emitting device disposed on the substrate. The organic light-emitting device includes a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer. In addition, the organic light-emitting display apparatus further includes a thin film encapsulating layer disposed on the organic light-emitting device. The thin film encapsulating layer includes at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material. The LVT inorganic material includes tin oxide and at least one of boron oxide (B₂O₃), bismuth oxide (Bi₂O₃), barium oxide (BaO), and ammonium dihydrogen phosphate (NH₄H₂PO₄).

21 Claims, 3 Drawing Sheets

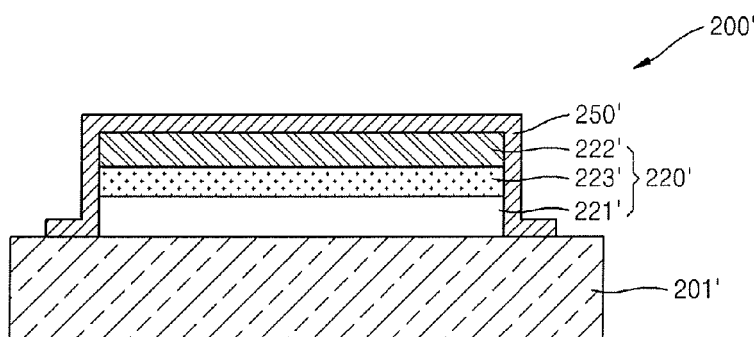


FIG. 1

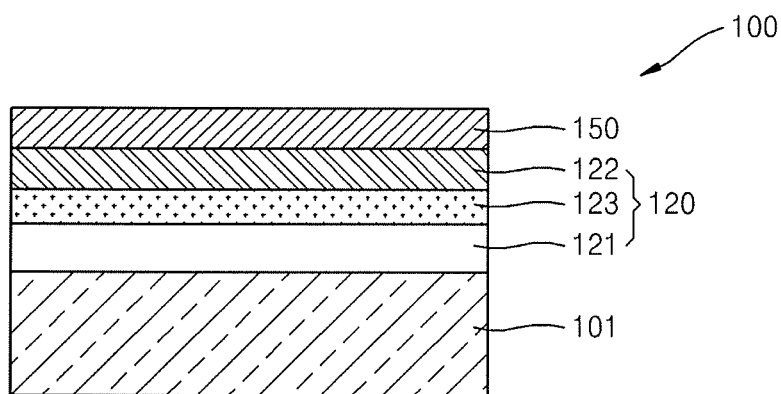


FIG. 2

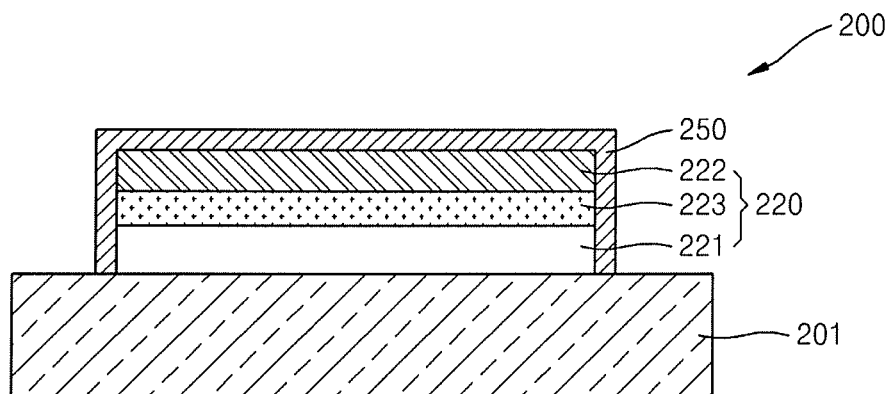


FIG. 3

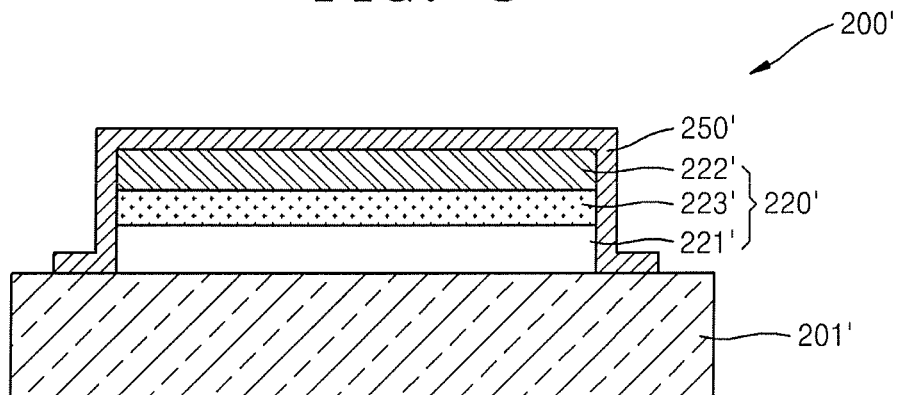


FIG. 4A

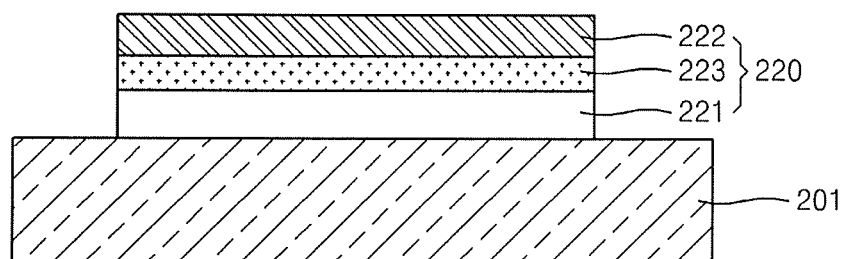


FIG. 4B

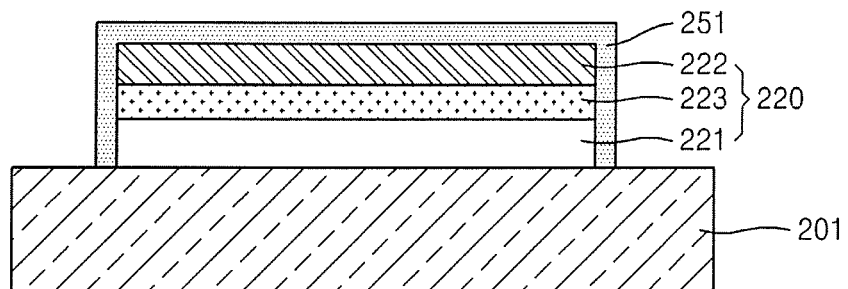


FIG. 4C

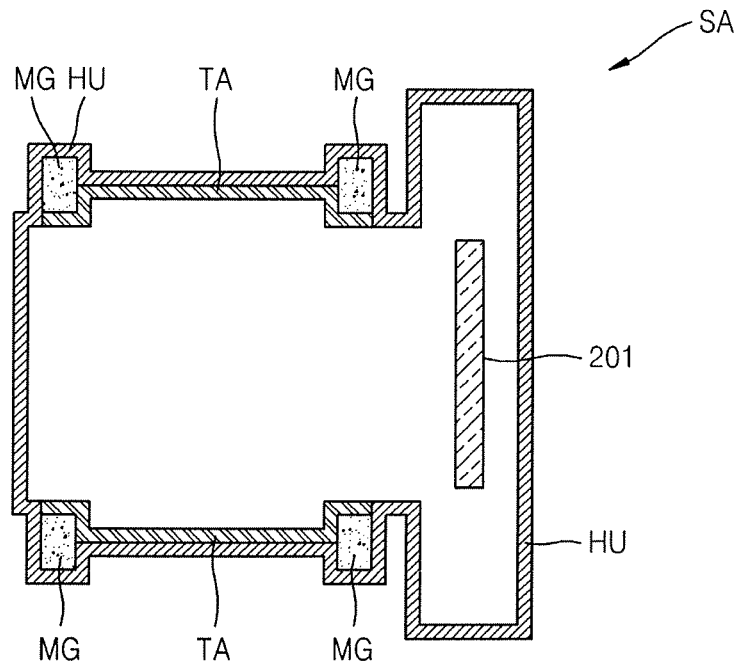
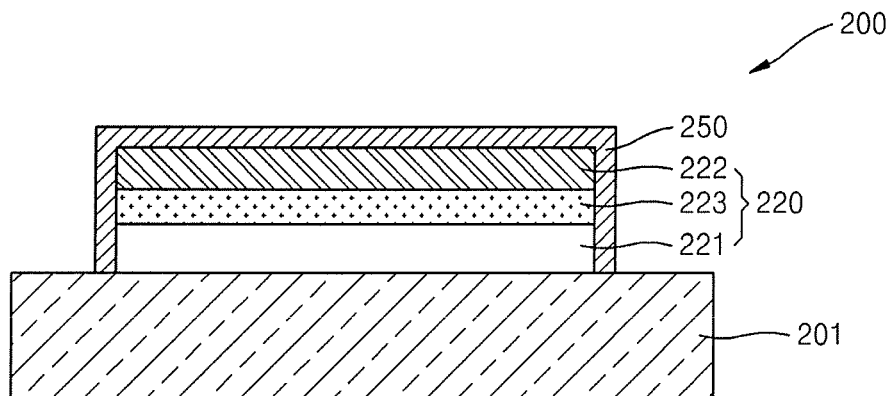


FIG. 4D



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ORGANIC LIGHT-EMITTING DISPLAY APPARATUS AND METHOD FOR MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Korean Patent Application No. 10-2013-0088269, filed on Jul. 25, 2013, the disclosure of which is hereby incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present disclosure relates to an organic light-emitting display apparatus and a method for manufacturing the same, and more particularly, to a display apparatus capable of increasing encapsulation characteristic and durability, and a method for manufacturing the same.

DISCUSSION OF THE RELATED ART

Recently, display apparatuses have been used in various ways. As the display apparatuses become slimmer and lighter, the use of the display apparatuses is increasing. An organic light-emitting display apparatus is a self-luminous display apparatus having low power consumption, wide viewing angles, and high image quality.

The organic light-emitting display apparatus includes an organic light-emitting device that includes a first electrode, a second electrode, and at least an organic emission layer disposed therebetween.

On the other hand, the organic light-emitting device may be vulnerable to external moisture and heat. Therefore, there may be a need for an encapsulating structure that encapsulates the organic light-emitting device.

One of methods for forming the encapsulating structure is a sputtering method which uses a sputtering target. However, it may be difficult to form the encapsulating structure by using a sputtering method. Consequently, it may be difficult to increase the durability and encapsulation characteristics of the organic light-emitting display apparatus when using a sputtering method.

SUMMARY

Exemplary embodiments of the present invention include a display apparatus capable of having increased encapsulation characteristics and durability, and a method for manufacturing the same.

According to an exemplary embodiment of the present invention, an organic light-emitting display apparatus includes: a substrate, and an organic light-emitting device disposed on the substrate. The organic light-emitting device includes a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer. In addition, the organic light-emitting display apparatus further includes a thin film encapsulating layer disposed on the organic light-emitting device. The thin film encapsulating layer includes at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material. The LVT inorganic material includes tin oxide and at least one of boron oxide (B_2O_3), bismuth oxide (Bi_2O_3), barium oxide (BaO), and ammonium dihydrogen phosphate ($NH_4H_2PO_4$).

The LVT inorganic material may further include at least one of tin fluoride, niobium oxide, and tungsten oxide.

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The LVT inorganic material may include tin oxide (SnO) and X, and in which X may be at least one of B_2O_3 , Bi_2O_3 , BaO, and $NH_4H_2PO_4$.

The LVT inorganic material may include tin oxide (SnO), tin fluoride (SnF_2), and X, and in which X is at least one of B_2O_3 , Bi_2O_3 , BaO, and $NH_4H_2PO_4$.

The LVT inorganic material may include tin oxide (SnO), tin fluoride (SnF_2), X, and niobium oxide (NbO), and in which X is at least one of B_2O_3 , Bi_2O_3 , BaO, and $NH_4H_2PO_4$.

The LVT inorganic material includes tin oxide (SnO), tin fluoride (SnF_2), X, and tungsten oxide (WO_3), and in which X is at least one of B_2O_3 , Bi_2O_3 , BaO, and $NH_4H_2PO_4$.

A viscosity transition temperature of the LVT inorganic material may be a minimum temperature capable of providing a flowability to the LVT inorganic material.

A viscosity transition temperature of the LVT inorganic material may be lower than a metamorphic temperature of a material included in the intermediate layer of the organic light-emitting device.

The organic light-emitting display apparatus may further include a planarization layer or a protection layer disposed between the organic light-emitting device and the thin film encapsulating layer.

The thin film encapsulating layer may cover a top surface and a side of the organic light-emitting device.

According to an exemplary embodiment of the present invention, a method for manufacturing an organic light-emitting display apparatus includes: forming an organic light-emitting device on a substrate, in which the organic light-emitting device includes a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer, and forming a thin film encapsulating layer on the organic light-emitting device. The thin film encapsulating layer includes at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material. The LVT inorganic material includes tin oxide and at least one of boron oxide (B_2O_3), bismuth oxide (Bi_2O_3), barium oxide (BaO), and ammonium dihydrogen phosphate ($NH_4H_2PO_4$).

The forming of the thin film encapsulating layer may be performed using a sputtering process.

The sputtering process may be performed using a sputtering target that includes tin oxide and at least one of B_2O_3 , Bi_2O_3 , BaO, and $NH_4H_2PO_4$.

The sputtering process may be performed while the substrate is moving in at least one direction.

The sputtering process may use two faced sputtering targets that do not face the substrate.

The method may further include: generating a plasma in a space between the two faced sputtering targets, and disposing the substrate to face the space where the plasma is generated.

One or more magnet units may be disposed to face a surface opposite to a surface facing the plasma in surfaces of the two faced sputtering targets.

The forming of the thin film encapsulating layer may include: forming a preliminary thin film encapsulating layer including the LVT inorganic material, and healing the preliminary thin film encapsulating layer.

The healing of the preliminary thin film encapsulating layer may be performed in a temperature range from a viscosity transition temperature of the LVT inorganic material to a metamorphic temperature of a material included in the intermediate layer of the organic light-emitting device.

The healing of the preliminary thin film encapsulating layer may be performed in a temperature range from a

viscosity transition temperature of the LVT inorganic material to a minimum value of metamorphic temperatures of a material included in the intermediate layer of the organic light-emitting device.

The healing of the preliminary thin film encapsulating layer may be performed at a viscosity transition temperature of the LVT inorganic material.

The healing of the preliminary thin film encapsulating layer may be performed by annealing the preliminary thin film encapsulating layer in a temperature range of about 80° C. to about 132° C. for about one hour to about three hours.

The healing of the preliminary thin film encapsulating layer may be performed in a vacuum atmosphere or an inert gas atmosphere.

In accordance with an exemplary embodiment, an organic light-emitting display apparatus is provided. The organic light-emitting display apparatus includes a substrate,

and an organic light-emitting device disposed on a top surface of the substrate. The organic light-emitting device includes a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer.

In addition, the organic light-emitting display apparatus further includes a thin film encapsulating layer covering a top surface and opposing sidewalls of the organic light-emitting device and having lower edges which protrude outwardly along the top surface of the substrate. The thin film encapsulating layer includes at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material. The LVT inorganic material includes tin oxide and at least one of boron oxide (B_2O_3), bismuth oxide (Bi_2O_3), barium oxide (BaO), and ammonium dihydrogen phosphate ($NH_4H_2PO_4$).

BRIEF DESCRIPTION OF THE DRAWINGS

Exemplary embodiments of the present invention can be understood in more detail from the following detailed description, taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic cross-sectional view of an organic light-emitting display apparatus according to an embodiment of the present invention;

FIG. 2 is a schematic cross-sectional view of an organic light-emitting display apparatus according to an embodiment of the present invention;

FIG. 3 is a schematic cross-sectional view of an organic light-emitting display apparatus according to an embodiment of the present invention; and

FIGS. 4A to 4D are views of a method for manufacturing an organic light-emitting display apparatus according to an embodiment of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. In this regard, exemplary embodiments of the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, exemplary embodiments are merely described below, by referring to the figures, to explain aspects of the present description. As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items. Expressions such as

“at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

It will be further understood that the terms “comprises” and/or “comprising” used herein specify the presence of stated features or components, but do not preclude the presence or addition of one or more other features or components.

It will be understood that when a layer, region, or component is referred to as being “formed on,” another layer, region, or component, it can be directly or indirectly formed on the other layer, region, or component. That is, for example, intervening layers, regions, or components may be present.

Sizes of elements in the drawings may be exaggerated for convenience of explanation. In other words, as sizes and thicknesses of components in the drawings are arbitrarily illustrated for convenience of explanation, exemplary embodiments are not limited thereto.

As used herein, the singular forms, “a,” “an,” and “the” are intended to include plural forms as well, unless the context clearly indicates otherwise.

Exemplary embodiments of the present invention will be described below in more detail with reference to the accompanying drawings. Throughout the disclosure, like reference numerals refer to like parts, and a redundant description thereof will be omitted.

FIG. 1 is a schematic cross-sectional view of an organic light-emitting display apparatus according to an embodiment of the present invention.

Referring to FIG. 1, the organic light-emitting display apparatus 100 includes, for example, a substrate 101, an organic light-emitting device 120, and a thin film encapsulating layer 150 including at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material.

The substrate 101 may be formed using various materials. For example, the substrate 101 may be formed of a transparent glass material including silicon oxide (SiO_2) as a main component. In addition, the substrate 101 may be formed of, for example, a transparent plastic material or a transparent quartz material. Further, in an embodiment, the substrate 101 may be, for example, a flexible substrate. Suitable materials for the flexible substrate include, for example, polyethylenenaphthalate, polyethylene terephthalate, polyacryl, polyimide, polyethersulfone, polyvinyl chloride, or combinations thereof.

The organic light-emitting device 120 is disposed on the substrate 101 and includes, for example, a first electrode 121, a second electrode 122, and an intermediate layer 123. For example, the first electrode 121 is disposed on the substrate 101, the second electrode 122 is disposed on the first electrode 121, and the intermediate layer 123 is disposed between the first electrode 121 and the second electrode 122.

In an embodiment, a buffer layer formed of, for example, silicon oxide (SiO_2), silicon nitride (SiN_x) and/or silicon oxynitride ($SiON$) may be further disposed between the first electrode 121 and the substrate 101. The buffer layer may provide a flat surface on the substrate 101 and may prevent moisture and gas from penetrating through the substrate 101.

For example, the first electrode 121 may function as an anode, and the second electrode 122 may function as a cathode. The order of the polarities of the first electrode 121 and the second electrode 122 may be reversed.

When the first electrode 121 functions as the anode, the first electrode 121 may include, for example, indium tin

oxide (ITO), indium zinc oxide (IZO), zinc oxide (ZnO), or indium oxide (In_2O_3) having a high work function. The first electrode **121** may further include, for example, a reflection film including silver (Ag), magnesium (Mg), aluminum (Al), platinum (Pt), palladium (Pd), gold (Au), nickel (Ni), neodymium (Nd), iridium (Ir), chromium (Cr), lithium (Li), ytterbium (Yb), calcium (Ca), aluminum-lithium (Al—Li), magnesium-indium (Mg—In), or magnesium-silver (Mg—Ag) depending on the purpose and design condition thereof.

When the second electrode **122** functions as the cathode, the second electrode **122** may be formed of a metal such as, for example, Ag, Mg, Al, Pt, Pd, Au, Ni, Nd, Ir, Cr, Li, Ca, Al—Li, Mg—In, or Mg—Ag. In addition, the second electrode **122** may include, for example, a light transmission material, such as ITO, IZO, ZnO, or In_2O_3 .

The intermediate layer **123** includes, for example, at least an organic emission layer. In addition to the organic emission layer, the intermediate layer **123** may include, for example, at least one selected from the group consisting of a hole injection layer, a hole transport layer, an electron transport layer, and an electron injection layer.

When a voltage is applied to the first electrode **121** and the second electrode **122**, visible light is generated from the intermediate layer **123**, and more particularly, the organic emission layer of the intermediate layer **123**.

In an embodiment, the organic light-emitting display apparatus **100** may include at least one thin film transistor electrically connected to the organic light-emitting device **120**. The organic light-emitting display apparatus **100** may include, for example, at least one capacitor electrically connected to the organic light-emitting device **120**.

In an embodiment, at least one planarization layer or at least one protection layer may be provided between the organic light-emitting device **120** and the thin film encapsulating layer **150**. The planarization layer or the protection layer provide a flat surface on the organic light-emitting device **120** and primarily protect the organic light-emitting device **120**. The planarization layer or the protection layer may be formed using various insulating materials. For example, the planarization layer or the protection layer may be formed using an organic material. For example, in an embodiment, the planarization layer may be formed of a material selected from the group consisting of benzocyclobutene (BCB), polyimide (PI), polyamide (PA), an acrylic resin and a phenolic resin. Also, in an embodiment, the protection layer may be formed of, for example, an inorganic insulating layer having a silicon oxide (SiO_2) layer, a silicon nitride (SiN_x) layer or a stacked structure thereof.

The thin film encapsulating layer **150** is provided on the organic light-emitting device **120**. The thin film encapsulating layer **150** includes, for example, at least one inorganic film including an LVT inorganic material.

The term “viscosity transition temperature” used herein does not refer to a temperature at which the LVT inorganic material completely changes from solid to liquid, but refers to a minimum temperature at which fluidity may be provided to the LVT inorganic material, that is, a minimum temperature at which a viscosity of the LVT inorganic material changes.

The viscosity transition temperature of the LVT inorganic material may be, for example, lower than the metamorphic temperature of the material included in the intermediate layer **123**. For example, the viscosity transition temperature of the LVT inorganic material may be lower than the minimum value of the metamorphic temperatures of the material included in the intermediate layer **123**.

The metamorphic temperature of the intermediate layer **123** refers to a temperature that may cause a physical metamorphosis and/or a chemical metamorphosis of the material included in the intermediate layer **123**. A plurality of metamorphic temperatures may be present depending on types and number of the material included in the intermediate layer **123**. For example, the viscosity transition temperature of the LVT inorganic material and the metamorphic temperature of the intermediate layer **123** may refer to a glass transition temperature (T_g) of the LVT inorganic material and a glass transition temperature (T_g) of an organic material included in the intermediate layer **123**.

The glass transition temperature may be measured by, for example, performing a Thermo Gravimetric Analysis (TGA) on the organic material included in the LVT inorganic material and the intermediate layer **123**.

For example, the glass transition temperature may be derived from a result of a thermal analysis using a TGA and a Differential Scanning calorimetry (DSC) with respect to the material included in the intermediate layer **123** (N_2 atmosphere, temperature range: room temperature to about 600°C . (10°C./min)-TGA, room temperature to about 400°C .-DSC, pan type: Pt pan in disposable Al Pan (TGA), disposable Al pan (DSC)), which may easily be recognized by those skilled in the art.

The metamorphic temperature of the material included in the intermediate layer **123** may exceed, for example, about 130°C ., but exemplary embodiments of the present invention are not limited thereto. As described above, the metamorphic temperature of the material included in the intermediate layer **123** may readily be measured through the TGA.

The minimum value among the metamorphic temperatures of the material included in the intermediate layer **123** may be, for example, about 130°C . to about 140°C . For example, the minimum value among the metamorphic temperatures of the material included in the intermediate layer **123** may be, for example, about 132°C ., but exemplary embodiments of the present invention are not limited thereto. As described above, the minimum value among the metamorphic temperatures of the material included in the intermediate layer **123** may be determined by obtaining the values of T_g through the TGA and selecting the minimum value among the various values of T_g .

For example, the viscosity transition temperature of the LVT inorganic material may be about 80°C . or higher. In an embodiment, the viscosity transition temperature of the LVT inorganic material may be, for example, in the range of about 80°C . to about 132°C ., but exemplary embodiments of the present invention are not limited thereto. For example, in an embodiment, the viscosity transition temperature of the LVT inorganic material may be about 80°C . to about 120°C ., or about 100°C . to about 120°C ., but exemplary embodiments of the present invention are not limited thereto. For example, in an embodiment, the viscosity transition temperature of the LVT inorganic material may be about 110°C .

The LVT inorganic material may be a single compound or a mixture of two or more kinds of compounds.

The LVT inorganic material includes, for example, tin oxide (for example, SnO or SnO_2). In addition, the LVT inorganic material further includes, for example, any one of boron oxide (B_2O_3), bismuth oxide (Bi_2O_3), barium oxide (BaO), and ammonium dihydrogen phosphate ($\text{NH}_4\text{H}_2\text{PO}_4$). The content of SnO may be, for example, about 20 wt % to about 100 wt %.

For example, the LVT inorganic material may further include one or more of tin fluoride (for example, SnF_2), niobium oxide (for example, NbO), and tungsten oxide (for example, WO_3), but exemplary embodiments of the present invention are not limited thereto.

For example, the LVT inorganic material may be

SnO and X ;

SnO , SnF_2 , and X ;

SnO , SnF_2 , X , and NbO ; or

SnO , SnF_2 , X , and WO_3 .

The X may be, for example, any one of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$.

Alternatively, in an embodiment, the X may be, for example, multiple. For example, the X may include B_2O_3 and BaO . In this case, the LVT inorganic material may be

SnO , B_2O_3 , and BaO ;

SnO , SnF_2 , B_2O_3 , and BaO ;

SnO , SnF_2 , B_2O_3 , BaO , and NbO ; or

SnO , SnF_2 , B_2O_3 , BaO , and WO_3 .

However, the present embodiment of the present invention is not limited thereto, and the X may include, for example, at least two of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$.

As all of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$ have an excellent reactivity with SnO , the LVT inorganic material may readily be formed. As B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$ each have a low reactivity with moisture, it is possible to prevent the thin film encapsulating layer **150** including the LVT inorganic material from being expanded by moisture or being peeled off from adjacent layers. Therefore, dark spots of the organic light-emitting display apparatus **100** are suppressed, and the durability thereof is increased.

As B_2O_3 has excellent chemical durability and a low melting point, the manufacturing process and encapsulation characteristic of the thin film encapsulating layer **150** by using the LVT inorganic material are increased. As BaO has excellent chemical durability and a high transmittance, a transmittance of the thin film encapsulating layer **150** is increased. $\text{NH}_4\text{H}_2\text{PO}_4$ effectively suppresses a reactivity with moisture while reacting with SnO .

For example, the LVT inorganic material may have the following composition, but the present embodiment of the present invention is not limited thereto. As described above, X may be, for example, any one of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$. Alternatively, in an embodiment, X may include, for example, at least two of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$.

1) SnO (80 wt %) and X (20 wt %); (for example, X means 20 wt % of B_2O_3 or 20 wt % of ($\text{B}_2\text{O}_3 + \text{BaO}$))

2) SnO (20-50 wt %), SnF_2 (30-60 wt %), and X (10-30 wt %) (where the total weight of SnO , SnF_2 , and X is 100 wt %);

3) SnO (20-50 wt %), SnF_2 (30-60 wt %), X (10-30 wt %), and NbO (1-5 wt %) (where the total weight of SnO , SnF_2 , X , and NbO is 100 wt %); or

4) SnO (20-50 wt %), SnF_2 (30-60 wt %), X (10-30 wt %), and WO_3 (1-5 wt %) (where the total weight of SnO , SnF_2 , X , and WO_3 is 100 wt %).

For example, the LVT inorganic material may include SnO (42.5 wt %), SnF_2 (40 wt %), X (15 wt %), and WO_3 (2.5 wt %), but exemplary embodiments of the present invention are not limited thereto.

When the thin film encapsulating layer **150** including the inorganic film of the above-described composition is formed, the viscosity transition temperature may be maintained to be lower than the metamorphic temperature of the intermediate layer **123**. Therefore, various types of defects,

which may be formed in the thin film encapsulating layer **150**, may be healed in a healing process to be described below.

In an embodiment, the thin film encapsulating layer **150** may include, for example, a film-formation component. The film-formation component may be, for example, inorganic particles formed during the film formation process of the thin film encapsulating layer **150**. As described below, the film-formation component may be healed in the subsequent healing process and form a portion of the thin film encapsulating layer **150**.

The organic light-emitting display apparatus **100** according to the present embodiment includes, for example, the thin film encapsulating layer **150** on the organic light-emitting device **120**, and the thin film encapsulating layer **150** includes, for example, the LVT inorganic material. Therefore, it is possible to prevent thermal damage to the intermediate layer **123** of the organic light-emitting device **120** and to increase moisture permeability characteristics thereof. In addition, the use of the thin film encapsulating layer **150** suppresses damage to the organic light-emitting display apparatus **100** even though various film-formation components may be generated.

According to the present embodiment, as the LVT inorganic material provided in the thin film encapsulating layer **150** includes, for example, SnO and one or more of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$, a reactivity with SnO is increased and a reactivity with moisture is suppressed. Hence, a manufacturing characteristic of the thin film encapsulating layer **150** is increased, and an encapsulation characteristic of the thin film encapsulating layer **150** is increased. Consequently, the failure of the organic light-emitting display apparatus **100** is suppressed, and the durability of the organic light-emitting display apparatus **100** is increased.

FIG. 2 is a schematic cross-sectional view of an organic light-emitting display apparatus according to an embodiment of the present invention. Referring to FIG. 2, the organic light-emitting display apparatus **200** includes, for example, a substrate **201**, an organic light-emitting device **220**, and a thin film encapsulating layer **250** including at least one inorganic film including an LVT inorganic material.

The organic light-emitting device **220** includes, for example, a first electrode **221**, a second electrode **222**, and an intermediate layer **223**.

For convenience, the following description will focus on differences between the above-described organic light-emitting display apparatus of FIG. 1 and the organic light-emitting display apparatus of the present exemplary embodiment of FIG. 2.

The present embodiment of FIG. 2 differs from the above-described organic light-emitting display apparatus of FIG. 1 in the structure of the thin film encapsulating layer **250**. In the present embodiment, the thin film encapsulating layer **250** is configured to cover a top surface and a side of the organic light-emitting device **220**. This may prevent the organic light-emitting device **220** from being damaged from moisture, external gas, and foreign substances. In addition, the thin film encapsulating layer **250** contacts the substrate **201**. Therefore, the thin film encapsulating layer **250** effectively encapsulates the organic light-emitting device **220**. As the thin film encapsulating layer **250** contacts the substrate **201**, the thin film encapsulating layer **250** may not be peeled off from the organic light-emitting display apparatus **200**, and the durability of the thin film encapsulating layer **250** is increased. In an embodiment, the thin film encapsulating

layer **250** may contact an insulating film or a conductive film additionally formed on the top surface of the substrate **201**.

As materials used to form the organic light-emitting device **220** and the thin film encapsulating layer **250** are substantially identical to those materials used to form the above-described organic light-emitting display apparatus of FIG. 1, a detailed description thereof will be omitted.

FIG. 3 is a cross-sectional view of an organic light-emitting display apparatus according to an embodiment of the present invention.

Referring to FIG. 3, the organic light-emitting display apparatus **200'** includes, for example, a substrate **201'**, an organic light-emitting device **220'**, and a thin film encapsulating layer **250'**. The thin film encapsulating layer **250'** includes, for example, at least one inorganic film including an LVT inorganic material. The organic light-emitting device **220'** includes, for example, a first electrode **221'**, a second electrode **222'**, and an intermediate layer **223'**.

For convenience, the following description will focus on differences between the above-described organic light-emitting display apparatuses of FIGS. 1 and 2 and the organic light-emitting display apparatus of the present embodiment of FIG. 3.

In the present embodiment, an edge of the thin film encapsulating layer **250'** protrudes outward. For example, a region contacting the substrate **201'** in the thin film encapsulating layer **250'** protrudes, leading to an increase in a contact area between the thin film encapsulating layer **250'** and the substrate **201'**. Due to the increase in the contact area between the thin film encapsulating layer **250'** and the substrate **201'**, it is possible to effectively prevent moisture, gas and foreign substances from penetrating through a gap between the thin film encapsulating layer **250'** and the substrate **201'**. In addition, as the thin film encapsulating layer **250'** is stably connected to the substrate **201'**, the durability of the thin film encapsulating layer **250'** and the organic light-emitting display apparatus **200'** is increased.

As materials used to form the organic light-emitting device **220'** and the thin film encapsulating layer **250'** are substantially identical to those materials used to form the above-described organic light-emitting display apparatuses of FIGS. 1 and 2, a detailed description thereof will be omitted.

FIGS. 4A to 4D are views of a method for manufacturing an organic light-emitting display apparatus according to an embodiment of the present invention.

In this embodiment, a method for manufacturing the organic light-emitting display apparatus **200** of FIG. 2 will be described below. However, this is merely for convenience of description, and it is clear that the present embodiment may also be applied to, for example, the organic light-emitting display apparatuses **100** and **200'** of FIGS. 1 and 3, respectively.

Referring to FIG. 4A, an organic light emitting device **220** is formed on a substrate **201**. The organic light-emitting device **220** includes, for example, a first electrode **221**, a second electrode **222**, and an intermediate layer **223**. The intermediate layer **223** includes, for example, at least an inorganic emission layer.

In an embodiment, a planarization layer or a protection layer may be, for example, further formed on the organic light-emitting device **220**.

Referring to FIG. 4B, a preliminary thin film encapsulating layer **251** for forming a thin film encapsulating layer **250** is formed. As described above, the preliminary thin film encapsulating layer **251** is formed using, for example, an LVT inorganic material. The forming of the preliminary thin

film encapsulating layer **251** may be performed using, for example, a sputtering process, a vacuum evaporation process, a low-temperature deposition process, an electron beam coating process, or an ion plating process.

For example, the LVT inorganic material having a composition $\text{SnO—SnF}_2\text{—X—WO}_3$ may be provided on the organic light-emitting device **220** through the sputtering process. In this case, as described above, X includes, for example, at least one of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$.

FIG. 4C exemplarily illustrates a method of forming the preliminary thin film encapsulating layer **251** including the LVT inorganic material on the organic light-emitting device **220** and the substrate **201** by using a sputtering apparatus SA.

Referring to FIG. 4C, the sputtering apparatus SA includes, for example, two faced sputtering targets TA within a housing HU.

The sputtering target TA includes, for example, SnO and X. As described above, X includes, for example, at least one of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$. For example, the sputtering target TA includes SnO , SnF_2 , X, and WO_3 , and X includes at least one of B_2O_3 , Bi_2O_3 , BaO , and $\text{NH}_4\text{H}_2\text{PO}_4$.

Magnet units MG are disposed on surfaces opposite to the surfaces facing the sputtering targets TA. The substrate **201** does not directly face the sputtering targets TA. For example, the substrate **201** is disposed to face a space between the two faced sputtering targets. Plasma is generated in the space between the two faced sputtering targets TA. Atoms of inert gas, such as, for example, argon (Ar), which has no direct relation to the sputtering, rarely directly travels towards the substrate **201**. Therefore, it is possible to prevent damage to the surface of the substrate **201** or the organic light-emitting device **220** formed on the surface of the substrate **201**.

In the present embodiment, the organic light-emitting device **220** has been formed on the substrate **201**. However, alternatively, in an embodiment, a planarization layer or a protection layer may be formed on the substrate **201** prior to forming the organic light-emitting device **220**. To effectively perform the process of forming the preliminary thin film encapsulating layer **251**, the process may be performed, for example, while the substrate **201** is moving in one or more directions. In this manner, the preliminary thin film encapsulating layer **251** having a desired thickness (for example, about 1 μm) may readily be formed.

In an embodiment, the preliminary thin film encapsulating layer **251** may include various defects such as, for example, a film-formation component, a pinhole, and an environmental component. The environmental component is, for example, an organic material or an inorganic material. The environmental component may be, for example, particles attached during the forming of the organic light-emitting display apparatus **200**. In addition, defects such as, for example, an empty space between the preliminary thin film encapsulating layer **251** and the organic light-emitting device **220** may be generated. The film-formation component refers to an aggregate particle of the LVT inorganic material that does not contribute to the film formation during the film formation of the preliminary thin film encapsulating layer **251**. The pinhole is a region where the LVT inorganic material is not provided.

The above-described defects of the preliminary thin film encapsulating layer **251** may serve as a passage of external environmental materials such as, for example, moisture or

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oxygen. This may cause progressive dark spots to be formed, which may reduce the life of the organic light-emitting display apparatus **200**.

Therefore, after the preliminary thin film encapsulating layer **251** is formed, a healing process is performed to form the thin film encapsulating layer **250** as illustrated in FIG. 4D.

The healing process is performed, for example, at a higher temperature than a viscosity transition temperature of the LVT inorganic material. For example, the healing process may be performed by annealing the preliminary thin film encapsulating layer **251** in the range from the viscosity transition temperature of the LVT inorganic material to the metamorphic temperature of the material of the intermediate layer included in the organic light-emitting device **220**. Alternatively, in an embodiment, the healing process may be performed by, for example, annealing the preliminary thin film encapsulating layer **251** in the range from the viscosity transition temperature of the LVT inorganic material to a minimum value of metamorphic temperatures of the material included in the intermediate layer of the organic light-emitting device **220**. Alternatively, in an embodiment, the healing process may be performed, for example, at the viscosity transition temperature of the LVT inorganic material. For example, the healing process may be performed by annealing the preliminary thin film encapsulating layer **251** in the range of about 80° C. to about 132° C. (for example, in the range of about 80° C. to about 120° C. or in the range of about 100° C. to about 120° C.) for about one hour to about three hours (for example, at about 110° C. for about two hours), but exemplary embodiments of the present invention are not limited thereto. When the temperature of the heating process satisfies the above-described range, the fluidity of the LVT inorganic material of the preliminary thin film encapsulating layer **251** may be achieved and the metamorphosis of the intermediate layer of the organic light-emitting device **220** may be prevented. To prevent the preliminary thin film encapsulating layer **251** from being exposed to the external environment through the pinhole, the healing process may be performed, for example, in an IR oven under a vacuum atmosphere or an inert gas atmosphere (for example, N₂ atmosphere or Ar atmosphere).

Due to the healing process, the LVT inorganic material included in the preliminary thin film encapsulating layer **251** may be fluidized. The fluidized LVT inorganic material may have a flowability. Therefore, during the healing process, the fluidized LVT inorganic material may flow in and fill a gap formed by the environmental component, the fluidized LVT inorganic material may flow in and fill the pinhole, and the film-formation component may be fluidized and fill the pinhole.

By forming the thin film encapsulating layer **250**, the organic light-emitting display apparatus **200** is completed.

In addition, alternatively in an embodiment, a healing process may be further performed. In other words, the heat resistance and mechanical strength of the thin film encapsulating layer **250** may be increased by performing the healing process two times.

As described above, according to embodiments of the present invention, the organic light-emitting display apparatus and the method for manufacturing the same may readily increase the durability and encapsulation characteristics thereof.

Having described exemplary embodiments of the present invention, it is further noted that it is readily apparent to those of ordinary skill in the art that various modifications

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may be made without departing from the spirit and scope of the invention which is defined by the metes and bounds of the appended claims.

What is claimed is:

1. An organic light-emitting display apparatus comprising:

a substrate;

an organic light-emitting device disposed on the substrate, wherein the organic light-emitting device comprises a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer; and a thin film encapsulating layer disposed on the organic light-emitting device, wherein the thin film encapsulating layer comprises at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material, wherein the LVT inorganic material includes tin oxide and at least one of boron oxide (B₂O₃), bismuth oxide (Bi₂O₃), barium oxide (BaO), and ammonium dihydrogen phosphate (NH₄H₂PO₄), wherein a viscosity transition temperature of the LVT inorganic material is lower than a metamorphic temperature of the intermediate layer.

2. The organic light-emitting display apparatus of claim 1, wherein the LVT inorganic material further includes at least one of tin fluoride, niobium oxide, and tungsten oxide.

3. The organic light-emitting display apparatus of claim 1, wherein the LVT inorganic material includes tin oxide (SnO) and X, wherein X is at least one of B₂O₃, Bi₂O₃, BaO, and NH₄H₂PO₄.

4. An organic light-emitting display apparatus comprising:

a substrate;

an organic light-emitting device disposed on the substrate, wherein the organic light-emitting device comprises a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer; and a thin film encapsulating layer disposed on the organic light-emitting device, wherein the thin film encapsulating layer comprises at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material, wherein the LVT inorganic material includes tin oxide and at least one of boron oxide (B₂O₃), bismuth oxide (Bi₂O₃), barium oxide (BaO), and ammonium dihydrogen phosphate (NH₄H₂PO₄), wherein the LVT inorganic material includes tin oxide (SnO), tin fluoride (SnF₂), and X, wherein X is at least one of B₂O₃, Bi₂O₃, BaO, and NH₄H₂PO₄.

5. The organic light-emitting display apparatus of claim 4, wherein the LVT inorganic material further includes niobium oxide (NbO).

6. The organic light-emitting display of claim 4, wherein the LVT inorganic material further includes tungsten oxide (WO₃).

7. The organic light-emitting display apparatus of claim 1, wherein a viscosity transition temperature of the LVT inorganic material is a minimum temperature capable of providing a flowability to the LVT inorganic material.

8. The organic light-emitting display apparatus of claim 1, wherein the thin film encapsulating layer covers a top surface and a side of the organic light-emitting device.

9. A method for manufacturing an organic light-emitting display apparatus, the method comprising:

forming an organic light-emitting device on a substrate, wherein the organic light-emitting device includes a first electrode, a second electrode, and an intermediate layer including at least an organic emission layer; and

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forming a thin film encapsulating layer on the organic light-emitting device, wherein the thin film encapsulating layer comprises at least one inorganic film including a low temperature viscosity transition (LVT) inorganic material, wherein the LVT inorganic material includes tin oxide and at least one of boron oxide (B_2O_3), bismuth oxide (Bi_2O_3), barium oxide (BaO), and ammonium dihydrogen phosphate ($NH_4H_2PO_4$), wherein when the thin film encapsulation layer is formed, the viscosity transmission temperature is maintained to be lower than the metamorphic temperature of the intermediate layer.

10. The method of claim 9, wherein the forming of the thin film encapsulating layer is performed using a sputtering process.

11. The method of claim 10, wherein the sputtering process is performed using a sputtering target that includes tin oxide and at least one B_2O_3 , Bi_2O_3 , BaO , and $NH_4H_2PO_4$.

12. The method of claim 10, wherein the sputtering process is performed while the substrate is moving in at least one direction.

13. The method of claim 10, wherein the sputtering process uses two faced sputtering targets that do not face the substrate.

14. The method of claim 13, further comprising:
generating a plasma in a space between the two faced sputtering targets; and
disposing the substrate to face the space where the plasma is generated.

15. The method of claim 14, wherein one or more magnet units are disposed to face a surface opposite to a surface facing the plasma in surfaces of the two faced sputtering targets.

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16. The method of claim 9, wherein the forming of the thin film encapsulating layer comprises:

forming a preliminary thin film encapsulating layer including the LVT inorganic material; and

healing the preliminary thin film encapsulating layer.

17. The method of claim 16, wherein the healing of the preliminary thin film encapsulating layer is performed in a temperature range from a viscosity transition temperature of the LVT inorganic material to a metamorphic temperature of a material included in the intermediate layer of the organic light-emitting device.

18. The method of claim 16, wherein the healing of the preliminary thin film encapsulating layer is performed in a temperature range from a viscosity transition temperature of the LVT inorganic material to a minimum value of metamorphic temperatures of a material included in the intermediate layer of the organic light-emitting device.

19. The method of claim 16, wherein the healing of the preliminary thin film encapsulating layer is performed at a viscosity transition temperature of the LVT inorganic material.

20. The method of claim 16, wherein the healing of the preliminary thin film encapsulating layer is performed by annealing the preliminary thin film encapsulating layer in a temperature range of about 80° C. to about 132° C. for about one hour to about three hours.

21. The method of claim 16, wherein the healing of the preliminary thin film encapsulating layer is performed in a vacuum atmosphere or an inert gas atmosphere.

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